"DELINEATION OF GROUNDWATER, DROUGHT AND FLOOD POTENTIAL ZONE USING WEIGHTED INDEX OVERLAY ANALYSIS AND GIS FOR DISTRICT PATNA, BIHAR, INDIA"

MAJOR PROJECT REPORT

Submitted in partial fulfilment of the requirement of

M.Tech, ENVIRONMENTAL ENGINEERING

Submitted by:

Nikhilesh Gaurav (2K19/ENE/11)

Under the guidance of

Dr. GEETA SINGH

(Associate Professor, Department of Environmental Engineering, DTU)

Nikhilesh Gaurav
31/07/2021

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(FORMLY DELHI COLLEGE OF ENGINEERING)

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CANDIDATE DECLARATION

I hereby certify that the work which is being presented in the report entitle “DELINEATION OF GROUNDWATER, DROUGHT AND FLOOD POTENTIAL ZONE USING WEIGHTED INDEX OVERLAY ANALYSIS (WIOA) AND GIS FOR DISTRICT PATNA, BIHAR, INDIA” in partial fulfilment of the requirements for the award of the degree of Master of Technology in Environmental Engineering under DTU, Delhi. It is an authentic record of my own work carried out during period from 2020 to 2021 under the supervision of Dr. Geeta singh.

The matter embodied in this thesis has not been submitted by me for the award of any other degree of this or any other University Institute.

NIKHILESH GAURAV

2K19/ENE/11

Place –Delhi
Date:

CERTIFICATE

This report entitled DELINEATION OF GROUNDWATER, DROUGHT AND FLOOD POTENTIAL ZONE USING WEIGHTED INDEX OVERLAY ANALYSIS AND GIS FOR DISTRICT PATNA, BIHAR, INDIA, Nikhilesh Gaurav is recommended for the major project topic, as per the requirement for M.Tech. Final Semester of Environmental Engineering under the supervision of Dr. Geeta Singh.

SUPERVISOR

Dr. Geeta Singh

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

Place –Delhi

Date –

ACKNOWLEDGEMENT

I would like to thank respected Dr. Geeta Singh, for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report.

Secondly, I would like to thank my local guardian who patiently helped me as I went through my work and helped to modify and eliminate some of the irrelevant or unnecessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

NIKHILESH GAURAV

2K19/ENE/11

M.Tech (Environmental Engineering)

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CONTENT

ABSTRACT

The geographical information system (GIS) has a broad range of applications for groundwater assessment, delineation, discovery, and resource management of drought and flood zones. The present project is the first effort to delineate the possible region for groundwater, drought and flood using a particular methodology. This study seeks a way to define the potential zone for groundwater, drought and flood for the district of Patna in Bihar state. For the study area, various thematic layers were prepared, such as digital elevation map (DEM), geomorphology, land use and land cover (LULC), soil, drainage density, precipitation, and slope. In order to construct the final groundwater, drought and flood potential zonation chart, the thematic layers were combined using the WIOA technique. The possible areas for groundwater have been demarcated into four zones: 1-poor, 2-moderate, 3-good and 4-very good. In the eastern parts of the district, very strong (GWPZs) were found, while in the west and mid regions, moderate and bad categories were found. Drought and flood potential danger areas were divided into four zones: 1-no risk, 2-low risk, 3-moderate risk and 4-high risk, respectively. In the middle part of the region, there was a higher risk of drought and a reduced risk of flooding in the eastern part of the area, an elevated risk of flooding in the eastern part of the area and a lower to no risk of flooding in the western and central regions. Utilizing well discharge data from 2013, the GWPZ map was validated using groundwater fluctuation statistics for pre- and post-monsoon periods. The groundwater, drought and flood potential zonation map built in the present study will be useful for scholars, scientists, implementers in exploring appropriate water exploration locations and implementing resource utilization.

KEYWORDS: - Drought and Flood zones, GIS, GWPZs, LULC, Patna, Weighted index overlay analysis (WIOA).

CHAPTER 1
INTRODUCTION

1.1 GENERAL

In all living life on earth, groundwater plays a major role and is the most valuable available freshwater resource on earth. Remarkable demands for consumption, coupled with advances in agricultural and industrial activities, are leading to an imminent need to maximize the utilisation of groundwater sources. Continuous pumping of groundwater leads to the alarming fall in the water table all over the world. Scientific data-building activities for the management of water resources started several years ago by means of proximal sensing as well as remote sensing, but even then, practical data-catering knowledge on groundwater availability, optimal permissible extraction. In India, the optimal value of allowed wells in the watershed continues to be decreased. Efficient artificial recharge systems need to be identified and built in order to increase the groundwater yield in depleted aquifers for future needs, and also to store excess surface water. Recharging groundwater is nothing but the flow of water during the natural cycle from unsaturated surface level to the saturated underground stratum. A study shows that by the year 2015, the net groundwater supply was around 398 billion cubic meters of water. This method assesses 35 % water available in the country. Per capita demand of water dropped to 15% in 2011 as a result of rapid population increase and the associated decline in natural water resources. Most rural communities and urban communities in India rely on groundwater owing their everyday needs. Regrettably, there is a decrease of groundwater levels due to the overuse of groundwater for cultivation and other inhumane uses. Following reports of poor precipitation with drying of crops, the Bihar government declared 8 out of 23 blocks of Patna district as drought-affected. As per the IMD, the monsoon season finished with the nation showing a rainfall deficiency in three states of India, which are Bihar, Jharkhand and West Bengal, the greatest rainfall deficiency has been reported. The IMD data indicates that Patna recorded 27 percent of the weak precipitation. This project will be very helpful in delineating drought zones in view of this pattern of drought occurrence and will enable the government to take the requisite measures to resolve it and set up facilities in drought-prone zones. India's most flood-prone state is Bihar. Over 70% of the geographical area as a whole is at risk of annual floods, putting lives at risk and contributing to major financial losses. Upstream from the Ganga, Patna is located. The influential banana cultivation on the banks of the river Ganga between Patna and Bhagalpur, based on the evaluation of hundred years of flooding in the Ganga, is also one of the reasons of the floods. The report of the Central Water Commission

(CWC) stated that the sedimentation at Ganga in Bihar is essentially due to the immense load of sediment from its northern tributaries, Ghaghra, Gandak and Kosi. In Patna, places such as Kankarbagh, Rajendra Nagar and their environs are susceptible to flooding. It will help to identify areas vulnerable to flooding, based on the severity of flooding, by delineating flood potential zones, which will assist local officials to set up emergency response plans and take action to resolve and prepare before the crisis occurs.

1.2 OBJECTIVES

- To overlay different thematic layers by using ArcGIS function overlay analysis under Spatial Analyst Tool.
- To delineate different Groundwater, Drought and Flood potential zones for district Patna of Bihar.
- To validate groundwater delineated by using well data by CGWB report.

CHAPTER 2
LITERATURE REVIEW

Subbarayan Saravanan et al [2020]. They have been using analytical hierarchy process and GIS to demarcate groundwater resources in the Gundihalla watershed in Karnataka, India, and found that the tools and techniques were highly effective because they allowed the author to decide based on the impact of the criteria mentioned, and GIS aided in better visualisation of the spatial variability of the result. The results were divided into five categories: very good, good, moderate, bad, and very poor zones, which accounted for 18.76 percent, 23.7 percent, 23.3 percent, 18 percent, and 16.4 percent of the total area, respectively. For places with similar hydrological, geological, and geomorphological qualities, the adopted approach of measuring the groundwater potential zone works well. These findings can be used by government officials and planners to conduct further research and execute water management measures in the affected area.

Biswajeet Pradhan [2009]. For the Bharangi river basin in Maharastra, India, he used satellite remote sensing data and GIS techniques to study groundwater potential zones for basaltic waterways, and discovered that the output map has three classes, with groundwater recharge potential courses currently happening in alluvial plains with poorly consolidated amygdaloidal sedimentary rock. He came to the conclusion that potentially high zones exist in places with low drainage density and moderate to low lineament density. This area is surrounded by basalt, a hard rock that is typically thought to be a poor aquifer.

Muzzafar Ahmad Sheikh et al [2017]. They identified groundwater potential zones in a part of India's National Capital Region. They concentrate on the use of remote sensing and geographic information systems (GIS) for identifying and demarcating groundwater potential zones in the semi-arid Sonipat region of Haryana. They came to the conclusion that competent management and methods are needed to explore this valuable resource in this portion of the district. Regulators, engineers, builders, scientists, and the regional water ruling body (CGWB) will find the GWPZ map developed in this study highly valuable in determining acceptable places for groundwater investigation. It can also aid in the development of appropriate groundwater exploitation plans to ensure the long-term viability of this valuable resource.

N. S. Mangesh et al [2011]. They used RS, GIS, and MIF approaches to designate groundwater potential zones in the Theni district of Tamil Nadu, India. They discovered that GIS and MIF approaches are effective in reducing time, labour, and cost, allowing for quick decision-making for long-term management of water resources. According to the researchers, the study can be used as a guide for planning future artificial recharge initiatives in the study area in order to ensure long-term groundwater use.

Javed Mallick et al [2014]. For New Delhi, India, they developed on a spatial and statistical method for delineating groundwater potential zones. They came to the conclusion that the groundwater potential map generated in this study is extremely valuable to planners, policy/decision-makers, researchers, and engineers looking for ideal sites to conduct resource investigationsIt can aid in the development of successful groundwater extraction plans for the research region, ensuring the long-term viability of this important resource. The methodologies utilised in this study are also applicable to generalised planning and environmental evaluation. Therefore, at a location or larger-scale location, where local geological and geographic heterogeneities may predominate, these methods may be less useful.

Reda Amar et al [2013]. They collaborated on a project called "An integrated strategy for groundwater potential zoning in Egypt's shallow fracture zone aquifers." They concluded that groundwater exists in SFZ aquifers based on GPR profiles taken in the GIS model's potential sites. Because scientific studies are more expensive, they propose using remote sensing and GIS techniques to choose areas for field geophysical studies before wells drilled.

Peryasamy Mageshkumar et al [2019]. A research paper from south India uses geospatial approaches to demarcate groundwater potential zones. They found that by virtue of their unique qualities of decreasing time, manpower, and easiness through visual interpretation, RS and GIS approaches are particularly effective and capable of defining groundwater potential recharge sites. Around 56 percent of the whole study area is covered by excellent to medium ground water potential zones.

Harikrishna Karanam et al [2014]. In the broader Vishakhapatnam municipal corporation area of Andhra Pradesh, India, they identified groundwater potential zones. Because of their low weathering and fracture character, they discovered that Charnohkite and Leptynite rock formations are poor water holding zones. Ground water exploration is more likely in places with Khondalite rock formations. The cause could be that the granite is more susceptible to weathering and fracturing than other types of rocks. They also discovered that, due to excessive draught, most wells are drying out, resulting in seawater intrusion in specific regions along the coast, notably in metropolitan areas.

Sitender et al [2011]. In the Mewat district of Haryana, India, researchers identified groundwater potential zones. They came to the conclusion that remote sensing and geographic information systems (GIS) have shown to be important instruments in defining groundwater potential zones based on the integration of multiple thematic maps. The geomorphology and slope of the area have a direct relationship with the presence of groundwaterThe presence of folds in a hard rock area influences the capability for groundwater potential. The study region is dominated by quaternary unconsolidated sediment layers with a fairly level slope. As a result, approximately 66 percent of the land has outstanding potential for groundwater, while 18 percent does have very high to great potential. The existence of lineaments influences the groundwater potential of residual hills, structural hills, and linear ridges with steep slopes and high drainage density.

Nityananda SAR et al [2015]. They studied Hydrologic delineation of ground water potential zones using geospatial technique for Keleghai river basin, India. They concluded that AHP and integrated RS-GIS algorithms are beneficial in identifying places that are conducive to the construction of a well making use of a variety of geo-informative themed maps. The physical and geological parameters influencing groundwater prospective are integrated in a map form presenting geographical data for locations with various reactions to groundwater great potential in the Keleghai river basin using a methodology. Produce accurate groundwater studies for the Keleghai river basin in order to aid future expansion plans. Furthermore, radar pictures may offer major groundwater mapping benefits in this area. To properly harness the existing and rising capabilities of the techniques, more RS and GIS-based watershed exploration with field investigations might be attempted.

S. S. Asadi et al [2007]. They studied Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India. Merging of Remote Sensing and GIS are great tools for the development of various electronic thematic layers and maps depicting geographic variation of water quality index, according to the analysis of the data gathered at various phases of the operation. Tracking contamination patterns and changes in relation to urbanisation is a critical challenge for attaining long-term groundwater management. An integrated remote sensing and GIS study demonstrates that it is a critical tool for evaluating and quantifying the effects of land use and land cover on ground water quality. Groundwater pollution control and treatment strategies are suggested holistically using spatial distribution maps of several pollution indicators to demarcate the location based availability of water contaminants in a broader perspective.

Anju Verma et al [2013]. They researched on Evaluation of ground water quality in Lucknow, Uttar Pradesh using remote sensing and geographic information systems (GIS). The study revealed that the quality of subsurface water in the studied area is highly correlated with land use. The drinking water in densely populated residential areas is extremely contaminated. Water quality is comparatively better in suburban areas with lower population density and built-up area. Water samples from suburban locations near the city, such as Thakurganj, Newajpur, and Sabahpur, demonstrate low water quality. As a result, certain practical actions must be taken as soon as possible to improve the drinking water quality through an effective management strategy.

M. Balakrishnan [2019]. They studied Groundwater Potential Zone Mapping using Geospatial Techniques in Walayar Watershed. According to the current study, very good groundwater potential zones cover 39.74 km2 of the whole studied area. The reason for the favourable subsurface water study area is due to factors such as the presence of highly weathered, low level incline resulting in modest surface spill-over, which indicates the region's penetration rate is moderate. It also shows that due to the low drainage density and adjacent stream channels, a significant amount of groundwater occurrence is quite likely. The geospatial is proof of the important function being played in investigating and demarcating groundwater resources in any place to a big extent with least effort, time, and labour. This technique produces a map that shows the region's subsurface water level. According to the findings, the groundwater potential zone map generated will serve as useful guidelines for organisers, designers, and leaders, allowing for swift decision-making in the management of groundwater assets, as well as site selection for groundwater inquiry and exploitation.

I.P. Senanayake et al [2013]. They studied Water Pollution Prevention Study Using Remote Sensing and GIS. The findings of this study show that Ambalantota has a substantial degree of artificial recharge capacity. Artificial recharge capability was determined to be high to moderate in around 49% of the Ambalantota area. The suitability map that results from this analysis, as well as the methods used in this study, will serve as a guideline for future water management efforts. With some tweaks, the methods employed here could be implemented in other parts of the world where there is a water shortage. Such efforts can be used to assess the possibilities for artificial recharge in arid zones in order to secure long-term groundwater use.

P.K. Singh et al [2014]. They studied the Assessment of Surface Water Potential and Land Degradation of Wakal River Basin Using RS & GIS. As these reservoir are used to deliver water sources in rural regions, activity recognition is designed to improve their water quality. Erosion is severe in most parts of the Wakal basin (25-50 tonnes per hectare per year), but it is extremely severe in a few spots (75 tonnes per hectare per year). In the districts surrounding Kotda and Kalakhetar, where even the Wakal River meets the Sabarmati River, the erosion problem is serious. It is critical to stop erosion by implementing treatment measures in the area utilising a watershed strategy. Ground rainwater gathering appears to be the only option for alleviating water scarcity and increasing agricultural production in the Wakal River Basin.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 STUDY AREA

Many factors, including DEM, geomorphology, drainage density, slope, land use land cover, rainfall, soil type, affect all these areas. Each of these parameters affects groundwater, drought and flood zones in its own and varied way. Therefore, the single criteria analysis does not yield fair results for groundwater capacity, drought and flood threats. In addition, all the maps listed above are helpful in determining potential zones for groundwater, drought and flooding.

Table 1 Information Source and Explanation

Parameter	Data explanation	Source
Geomorphology	Downloaded and listed in to the 30-m raster data resolution.	Bhukosh-Geological Survey of India (https://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx)
LULC	National boundaries conform to that published by the Survey of India. Downloaded and listed in to the raster data resolution.	NASA ORNL DAAC (https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1336)
Soil	Re-categorized to raster data in to the 30-m resolution. Scale 1:50,000.	FAO GeoNetwork (http://www.fao.org/geonetwork/srv/en/)
Drainage density	Obtained from DEM using different ArcGIS commands like Flow Accumulation, Watershed and Drainage Density.	ASTER Global DEM Model Version3 (https://search.earthdata.nasa.gov/search)
Rainfall	The rainfall measurements of the rain-gauge locations was interpolated by using IDW method for the study region.	Climatic Research Unit (CRU) (https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_4.04)

DEM	Downloaded and listed in to the 30-m raster data resolution.	ASTER Global DEM Model Version3 (https://search.earthdata.nasa.gov/search)
Slope	Obtained from DEM using different ArcGIS commands like Surface and Slope.	ASTER Global DEM Model Version3 (https://search.earthdata.nasa.gov/search)

The current study is being conducted in Patna, Bihar. The primary urban centre of Patna is situated at coordinates of 25 ° 35 '38.74' N and 85 ° 8 '15.23' E with an altitude of 53 m (173 feet) elevated sea level. Patna is stationed on the Ganga River's southern coast, and also the central Ganga region is surrounded by the convergence of Sone, Gandak and Punpun, 3 other rivers. The area has a subtropical, mostly homogeneous climate. It is characterized by fairly hot summers to relatively cold winters of a moderate sort. It ranges in the summers from 43°C to 30°C and in the winters from 21.4°C to 5°C. The summer begins in April and peaks in June/July with the temperature rising to 43°C. The rains last until early October through August & September and the monsoon receives medium to strong rainfall. During summers, relative humidity goes up to 100 per cent. The region is part of the Indo-Gangetic alluvium, one of India's three major physiographic divisions, which divides the northern extra-peninsular region from the southern peninsular region. Since middle Pleistocene times, the level plain is believed to be the outcome of a granular filling of a large depression with alluvial sediments. The area forms part of the Ganga flood plains and has a flat relief that is monotonous. The region under study is underlined by quaternary-age alluvial sediments. In the Archaean basement, the quaternary sediments were deposited unconformably. In the study zone, farming conditions rely primarily on the soil, topography and irrigation systems prevalent in the area. The area consists mainly of four soil types, ranging from relatively well-drained to poorly-drained, acidic to mildly alkaline and mild to strongly textured. From the agricultural point of view, only four soil types can be recognized as soft to hard in texture, namely Heavy Clay (Kewal), Loam (Domat), Fairly Light Soil (Balsundri) and Basic (Rehara) respectively. The capital of Bihar, Patna, enjoys the unique value of becoming one of the country's richest surface water banks. From Haldia mostly on Bay of Bengal, across the tip of the Jharkhand province, across the centre of Bihar and then to Allahabad in Uttar Pradesh, this road of navigable water passes. The city has a fixed terminal on the National Waterway No.1. The chain of inland waterways along the river Ganga connects it to Kolkata. Throughout the year, the Ganges becomes accessible and goods can be transported by substantial boat traffic. Smaller rivers, such as Punpun and Dardha, can only be navigated during precipitation as they're used to transport farm produce to the grain market of Fatuha. The greater level of disasters is defined by environmental vulnerability by reflecting on the entirety of partnerships in a particular social context, a condition that produces a tragedy in accordance with the forces of the environment. In the delineated region, vulnerabilities like flooding and drought arise. Patna falls within the flood risk zone. A number of embankment were built along the River Punpun to regulate the floodwaters. The spill over from the river Ganga and Punpun during the monsoons appears to flood Patna and cause illness to spread. Therefore, the river must be channelized and a proper disaster mitigation strategy must be planned and implemented. In addition to being flood-prone, Due to droughts, Patna seems to be at threat as its 8 out of 23 blocks are situated in areas vulnerable to drought. The requisite steps must be accounted within order to overcome these risks and in a cost-effective manner.

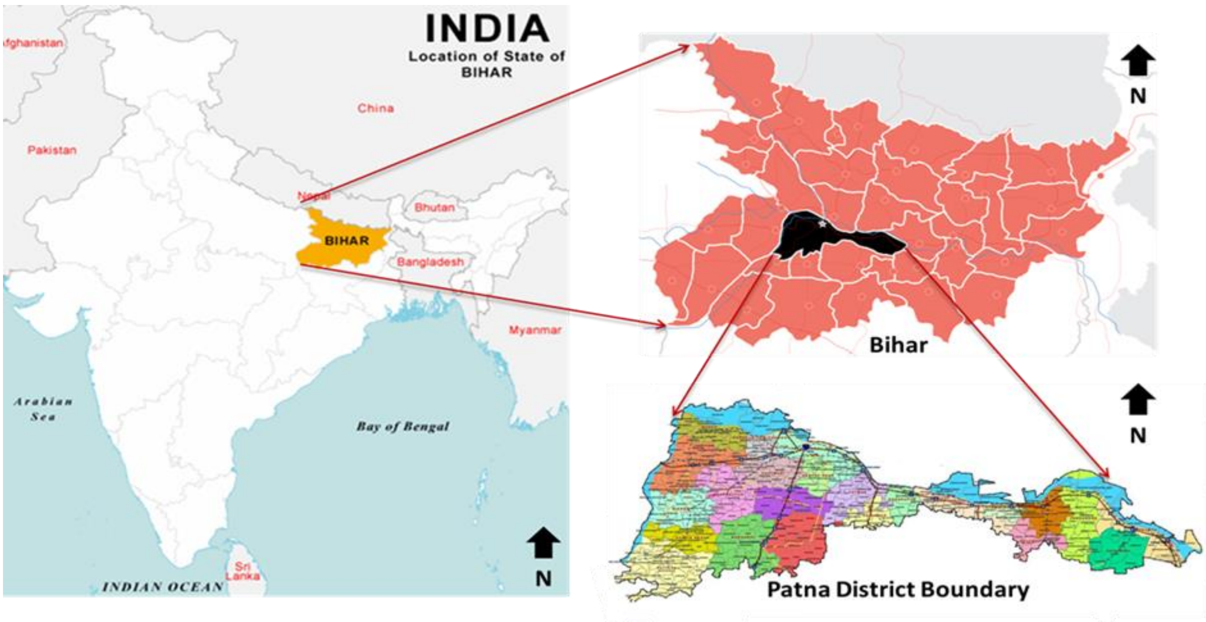


Figure 1 Location map for the research area.

In order to classify the potential GWPZ, drought and flood zones for the Bihar district of Patna. Seven input parameters were considered to define the existence and source of potential, such as DEM, geomorphology, slope, precipitation, drainage density, soil, and land use/land cover. For all of these factors, a digitized dataset was created by extracting data from multiple sources. Bhukhosh platform used on a ratio of 1:50,000 to collect map data such as geomorphology and land use. To develop a new elevations model through which elevation, slope, and flow depth may be derived, ASTER global DEM model version3 images with a resolution of 30 m were used. The soil map was obtained through a link (http://www.fao.org/geonetwork/srv/en/) on a ratio of 1:50,000 from the FAO. The rainfall information was collected using the link (https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_4.04/cruts.2004151855.v4.04/pre/) from CRU website. To acquire a rainfall forecast for said entire region, the station rainfall data was interpolated. Under the GIS environment, every impacting factor was geo-referenced and analysed and generated as distinct map layers. The 2013 data for the water level was downloaded from the Central Groundwater Control Board (CGWB). In order to render the interpolation map via the IDW technique in ArcGIS 10.8, this data was imported into the GIS environment. In ArcGIS 10.8, the groundwater potential zones, drought and flood potential zones were derived by overlaying all of the geospatial maps in the form of weighted overlay techniques by using analysis tool. Within each thematic map, a score was provided by weighted overlay analysis for each estimated object, and weights were allocated based on layer effects. Using data on subsurface water variation collected from the CGWB, the final outcome received were verified for ground data.

3.2 GIS

A geographic information system (GIS) is a technology database that stores, stores, checks, and displays data about locations on the Earth's surface. GIS can help individuals and organisations better understand geographical patterns and relationships by connecting seemingly unconnected data. The White House specifies geographic information network as "the technology, regulations, standards, human resources, and related activities essential to gather, process, transmit, use, preserve, and conserve spatial data." GIS technology is an important aspect of this infrastructure. Any input that involves a location can be used by GIS. The region can be specified in a variety of ways, including longitude and latitude, location, and Postcode. GIS allows you to compare and examine many different sorts of data. Data on people, such as census, income, and education level, can be included in the system. It may contain information on the terrain, such as the placement of streams, various types of vegetation, and various types of soil. It could include details regarding factory, agricultural, and school locations, as well as storm drains, highways, and power transmission lines. People can use GIS technology to compare the positions of various objects to see how they relate to one another. A single map may, for example, include places that cause pollution, such as factories, as well as areas that are sensitive to environmental changes, such as wetlands and waterways, employing GIS. A map like this would aid in determining where water resources are most vulnerable.

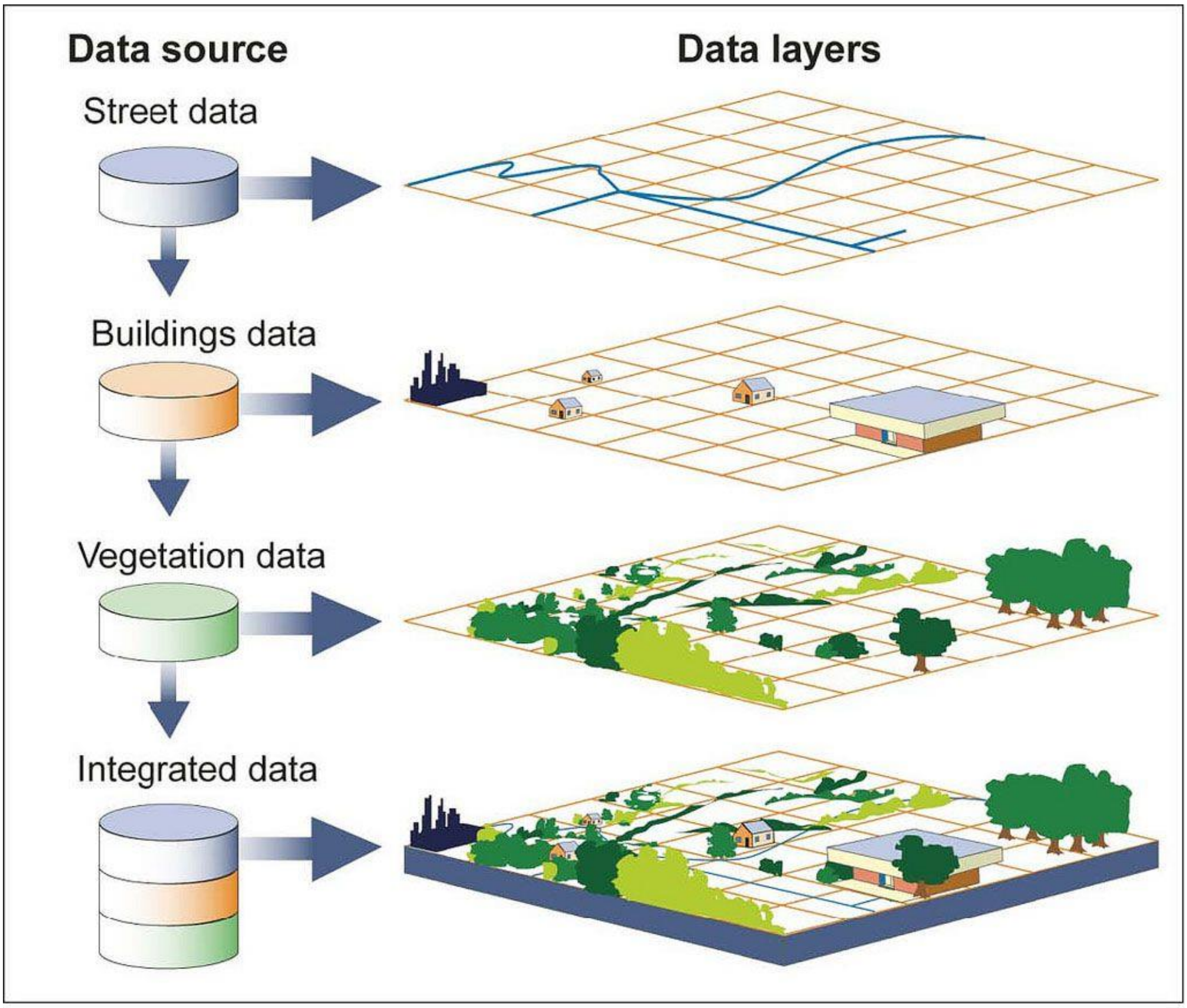
3.3 SPATIAL RELATIONSHIPS

Spatial linkages and linear connections can be seen using GIS technique. Topography, such as agricultural fields and waterways, can be displayed through spatial relationships. They may also show land-use patterns, such as where parks and housing complexes are located. GIS should align the data from all of the many maps and sources so that they all fit together on the same scale. The link between the length on a map and the horizontal measurements on Earth is known as a scale. A globe map can depict either the right size or shape of countries, but not both at the same time. GIS integrates information from maps created with divided into various so that all of the material may be presented using a single projection.

3.4 GIS MAPS

After all of the needed data has been entered into a GIS system, it can be merged to create a range of different individual maps, depending on which data layers are included. Relating landforms with human activities is one of the most common applications of GIS technology. GIS maps, for example, can show what man-made features are near landforms, such as whether residences and businesses are in flood-prone areas. GIS maps could be used to display information such as population density and quantities. GIS can, for example, display how many specialists are in a neighbourhood in relation to the population. Three-dimensional photographs are frequently created using GIS systems. Geologists researching quake faults, for example, will benefit from this. GIS technologies make upgrading maps a lot easier than directly upgrading maps. Data that has been updated can simply be imported into an existing GIS programme. After then, a new map can be printed or viewed on a computer screen. This eliminates the time-consuming and costly procedure of generating a map from the equation.

There is no limit to the kind of information that can be analysed using GIS technology.



Source: GAO.

Figure 2 Different layer of integrated data of map

3.5 GIS INTERPOLATION

Interpolation with inverse distance weighting (IDW) is a tool used to use the parameters of known sampling locations to approximate the intensity of that attribute at the unidentified sampling locations. The interpolation is focused on assumption that the known position has an impact value that decreases with the distance and hence the measuring of the inverse length of the term. This form of interpolation is fundamental and user-friendly, usable in almost any GIS. In ArcGIS 10.8, the IDW interpolation of various parameters of water quality was carried out.

3.6 DETERMINATION OF RANKS AND WEIGHTS USING WEIGHTED INDEX OVERLAY ANALYSIS

Depending on its effect on the analysis, WIOA is a method of giving due weight to the individual features. Its benefit would be that the human judgment can be integrated into this analysis. Assigned weights are the uniqueness of a parameter set in the task to achieve the study's objective (S. P. Rajaveni et al. 2017). Every thematic map of the occurrence of groundwater, drought and floods, such as DEM, geomorphology, LULC, slope and drainage density, rainfall, soil, has its own signature. Others experience this in order to get an integrated view of the field of research by manually overlaying the layers (Roy B et al. 2004). In GIS, this data is overlaid geographically. Depending on the capacity of groundwater, drought and flood, LULC is measurably put into the following categories, such as DEM, geomorphology, rainfall, slope, drainage density, soil. (i) Poor, (ii) Moderate, (iii) Good, and (iv) Very good for GWPZs and four zones for drought and flood potential danger zones: 1-no risk, 2-low risk, 3-moderate risk and 4-high risk. Based on the awareness of the interdependency between the layers, and based on their contribution to the capacity of groundwater, sufficient weight is presented to each class of a specific thematic layer for drought and flood intensity. Based on the weights allocated to individual layer (layer weight) and class, the thematic maps compiled from the above mentioned study are categorized (class weight). In this study evaluation scale was used as 1 to 5 for all three potential zones. The optimized thematic maps are overlaid and incorporated with the use of ground control points and final maps have been prepared for GWPZs, drought and flood zones.

3.7 OVERLAY ANALYSIS IN GIS

GIS relies heavily on spatial analysis. There are two ways to go about it. The first is vector-based analysis, and the second is raster-based analysis. Many government agencies have invested heavily in GIS deployments since the 1960s, including the procurement of hardware and software and the creation of massive databases GIS, in fact, is a powerful tool for creating maps and statistical reports from a database. GIS capabilities, on the other hand, goes far beyond mapping and report generation. The most essential uses of GIS are spatial analytic skills, in addition to basic functions linked to automated cartography and data base management systems. Because a GIS organises spatial data, it should be able to answer complicated spatial problems. Indeed, GIS is frequently used to build functions required for performing spatial analyses that are not available in cartographic programmes or database management systems.

3.8 GIS USAGE IN SPATIAL ANALYSIS

Identification is the process of interrogating geographic features and retrieving associated attribute information using a GIS. By querying and analyzing data, it can create a new set of maps. It also generates fresh data through spatial operations. Some analytical procedures using a GIS are discussed here. The following GIS operating procedures and analytical tasks are especially beneficial for geographical analysis:

- Operations on a single layer
- Spatial overlay/multi-layer operations.
- Modelling of space.
- Modelling in a geometrical approach.
- Spacing between geographical data is calculated.
- Area, length, and circumference are all calculated.
- Buffers that are geometric in nature.
- Analysis of point patterns.
- Network analysis.

3.9 WEIGHTED INDEX OVERLAY ANALYSIS

Overlay analysis is a GIS procedure that involves overlaying many layers of datasets representing different topics to analyse or uncover relationships between them. Overlay analysis creates a composite map by combining the attributes and geometry of several datasets or entities. The operations of comparing variables over various coverages are known as overlay. By combining data from multiple input data layers, spatial data sets are formed in the overlay analysis. One of the most prevalent and powerful GIS techniques is overlay analysis. It determines what is on the top layer by analysing many layers with common co - ordinates. Overlaying procedures integrate data from the same or distinct entities to generate new geometries and units of change. Overlay operations perform a variety of analyses, such as cropping patterns in the field, ethnic population domination in a region, age and sex composition of a region, and surface physical morphologies. Because it is performed by combining and seeing together various data sets that share all or part of the same area, it is also known as spatial overlay. As a result of this combination, a new data set identifying geographical linkages has been created. Map overlay is utilised in both vector data overlaying and raster data overlaying.

3.10 APPLICATION OF OVERLAY OPERATIONS

A suitable model is being used to determine the optimal placement for a new school, hospital, police station, industrial corridors, and other similar structures. In this concept, certain land uses are more beneficial to the construction of a new school than some others. For example, forest and farmland were more beneficial than residential properties. This institution was to be built on flat terrain, near recreation areas, and away from current schools. Keep in mind a few things when it comes to the site appropriateness overlay.

- Criteria selection
- Categorize the information according to the criteria.
- Overlay (Boolean or Map Algebra)
- Collection and visualisation of a suitable location.

3.11 GEOMORPHOLOGY

Geomorphological maps are visual descriptions of a landscape that show structures and shallow subsurface elements. These maps can be used as a preparatory tool for forest management and topographic and geomorphologic risk assessment, as well as offering basic information for other applicable fields of environmental science like landscape ecology, forestry, and soil science. These maps are classified as either basic or analytical, as well as derived or specialised. While basic maps depict the landscape's observed elements, derived maps are centred on a specific topic or application. Basic maps can either focus on specific landscape elements, such as the morphology of dynamic processes, or provide a comprehensive perspective of the landscape pattern and progression.

3.12 DRAINAGE DENSITY

The separation of river channel is characterised as the drainage density. It's a measurement of the total length of all orders' stream segments per unit area. Permeability is inversely proportional to drainage density. Rainfall infiltration is reduced as a rock becomes less permeable, resulting in a concentration of surface runoff. The line density analysis tool in ArcGIS software is used to calculate the drainage density of the research area. The climatic and physical factors of the drainage basin influence drainage density. It is a measure of a drainage basin's infiltration and permeability, as well as the shape of the hydrograph. The climatic and physical factors of the drainage basin influence drainage density.

3.13 SLOPE

A slope map is a topographic map that depicts variations in elevation in great detail. A slope map is used by architects, landscape designers, and water control planners to assess a property. To make one of these maps, you'll need a lot of information. Predicting the stream of water is one of the most useful applications of a map. Buildings and parking lots can heave and shift as a result of ground water. Storm runoff can also cause property damage. A slope map may also show the location and depth of utility lines. The elevation information is overlaid with aspect data on an aspect-slope map. The isolines on the map are shaded to indicate the direction of view. These maps are used, among other things, to illustrate the views of prospective building tenants, the efficiency of solar energy devices, and the ideal placements for fruit or decorative trees.

3.14 RAINFALL

A map depicting the rainfall distribution across a specific area. The collecting of rainfall data for the district of Patna was the first phase in the map's development. The information he gathered was saved as attribute data in the ArcGIS environment. Now, a rainfall map was created utilising various colour combinations, with rainfall inside a specific range being represented by a specific colour, and so on. The map's final editing was completed, and legends, scale, and other features were added.

3.15 SOIL

A soil map is a geographic portrayal of the variety of soil types and/or soil attributes (soil pH, textures, organic matter, horizon depths, and so on) in a given area. A soil survey stock, or soil survey, is usually the end outcome of a soil classification inventory. Soil maps are frequently used in projects such as site characterization, zoning, agricultural production, protecting the environment, and others. Conventional soil maps usually only show the general distribution of soils and come with a soil survey report. Digital soil mapping techniques are used to create a large number of new soil maps. Traditional soil maps are typically less context-rich and show less spatial detail than these maps. Soil maps created with (geo) statistical methods also include a concept complexity estimate. Soil maps are available in a variety of digital vector and raster configurations in the digital age, and they are used in a variety of geosciences and environmental engineering applications. Soil maps are simply visualizations of the soil resource inventories that are using these in a Soil Information System (SIS), of which a Soil Geographical Database is a major component.

3.16 LULC

Map of (LULC) give information to help users comprehend the current terrain. Annual LULC data stored in national spatial databases will allow for the monitoring of agricultural ecosystems, forest transformations, waterbodies, and other spatial pattern. Besides the collection of LULC data, annual Land use / Land cover layout is conducted out at a scale of 1: 250000 and net seeded area is estimated. At a scale of 1: 50000, land use/land cover data is generated every five years. At a scale of 1: 10000, land usage and land cover are generated, which is important for water and land resource planning at the village and taluk levels. LULC is a broad term that describes the categorization or classification of human activities and natural features on the landscape across time using established quantitative and qualitative research methods of analysis of acceptable source materials.

3.17 DEM

A DEM is a three-dimensional computer graphical representation of elevation data used to show terrain on a planet, moon, or asteroids. A discrete worldwide grid is referred to as a "global DEM." DEMs are the most basic element for digitally produced solvable and are frequently used in GIS. DEM is a generic word for digital surface model DSMs and digital terrain modelDTMs that solely represent height information without any additional surface characterization. DEMs are frequently created using data gathered through remote sensing techniques, although they can also be created by land surveying. Although the digital elevation model is a matrix of values, the information from such a DEM is frequently displayed in visual form to obtain relevant to people.

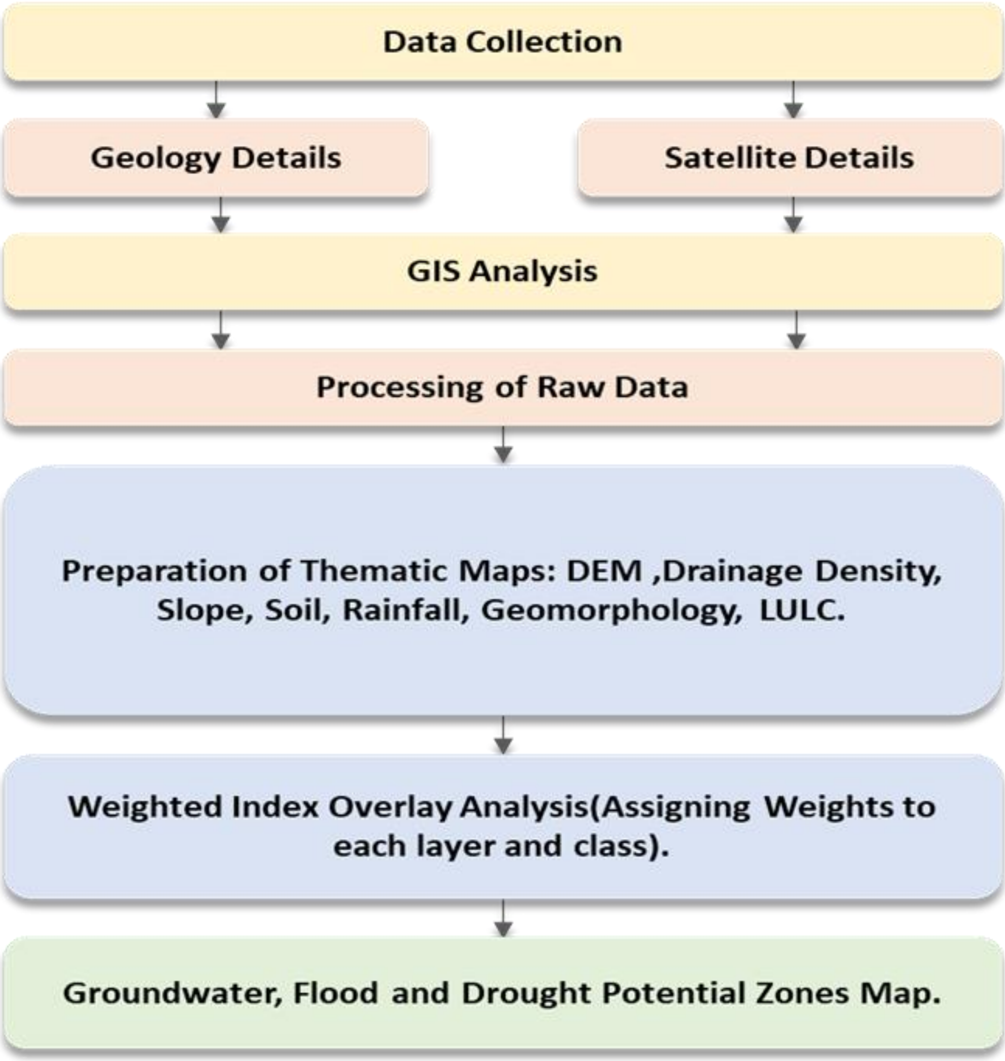


Figure 3 Methodology Flowchart

CHAPTER 4
RESULT AND DISCUSSION

Seven parameters considerably influenced the GWPZ, drought and flood zones delineation in Patna district of Bihar. The results of each attribute and the ranks and weights assigned to them are as shown below. Table 3, 4 & 5 illustrates how each parameter was rated and how much weight it was given in GWPZs, drought and flood potential zones respectively.

4.1 GEOMORPHOLOGY

The geomorphology of any area reflects the structure of the subsurface, which is highly important in the regulation of groundwater (Krishna AP et al. 2018).Based on its impact on GWPZs, drought and flood zones, the spatial geomorphology map was attributed to the weight. The area of study is geomorphologically divided into five groups, i.e. Younger Alluvial Plain, Older Flood Plain, Active Flood Plain, River, Pond, and Waterbodies. These six topographical units were grouped into four groups to make the allocation of rank and weight easy, in which Younger Alluvial Plain which is about 421.405km^2 in area of total geomorphological formation in the study region and comprises 12.90%, is assigned low rank as it is located on elevated side of district having less influence on GWPZs and flood zones but higher rank for drought zones as it is elevated more than other classes so water availability will be less as compared to other classes. Older Flood Plain and Active Flood Plain constitute about 2201.89km^2 (67.38%) and 527.206km^2 (16.13%) in area(percentage) respectively of the research area's entire geomorphological composition and assigned moderate and little high value respectively for GWPZs because these are flood plains and will help recharge ground water more.

For flood potential zones, Older Flood Plain and Active Flood Plain are ranked high and higher values respectively, because of more possibility of occurrence of flood in these regions. For drought potential zones Older Flood Plain and Active Flood Plain are ranked moderately because of less chances of flood occurrence in these regions. Similarly, River, Pond, Waterbodies all constitutes of total 117.3276km^2 (3.59%) in area (percentage) and ranked highest because of water availability throughout the year and will help in recharge of groundwater and also study area is mainly plain region. For flood potential zones these are ranked high because mainly flood occurs in this study zone because of waterbodies and for drought zones they are ranked lowest because of very less chance of occurrence of drought in these regions, because of availability of water throughout year.

The geomorphology of the region studied is shown in figure-4.

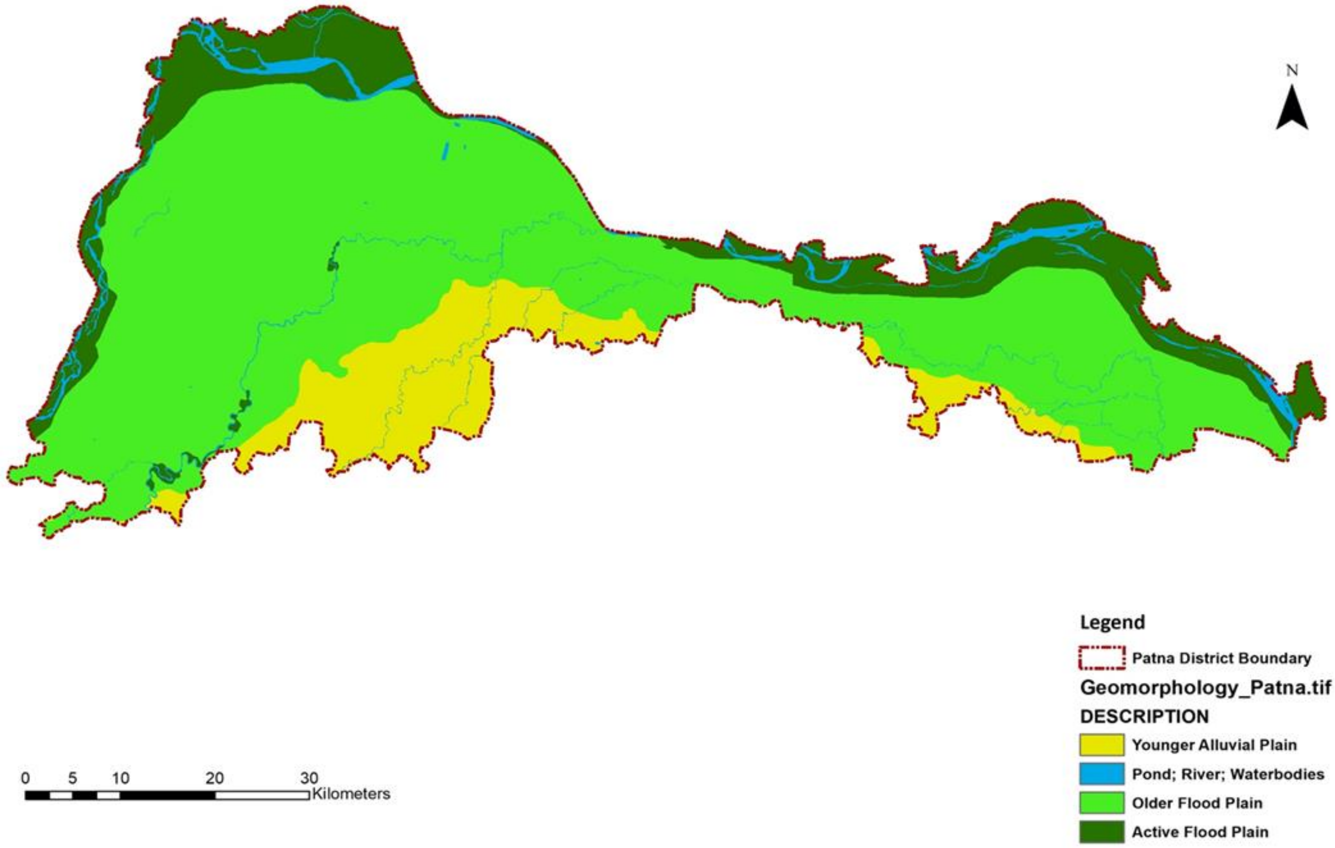


Figure 4 Geomorphology map of Patna District.

4.2 DRAINAGE DENSITY

Drainage density being known as the proportion of the total runoff channel length of the region to the area of the entire drainage basin. It relies on the characteristics of land, slope, and near surface topography (S. P. Rajaveni et al. 2017).Using the ASTER Global DEM Model Version3 30-m resolution images, In the ArcGIS, both flow accumulation and the drainage density map were extracted for the study area. The analysis area's drainage density varies from 0.0028 to 4.75 m/m^2. The ranking was given in a manner that there would be more infiltration where there's more streams passing from the field. If there is more infiltration, the water will go below ground and it will be easier to recharge groundwater resources.

The region with better drainage density would have greater value and lower drainage density will have smaller value for the classification of flood potential zones.

Promising areas with higher drainage density will have lower rankings for the classification of drought zones and areas with lower drainage density will have top ranking because less drainage will have more drought possibilities. In figure- 5, the drainage density of the sample area is given.

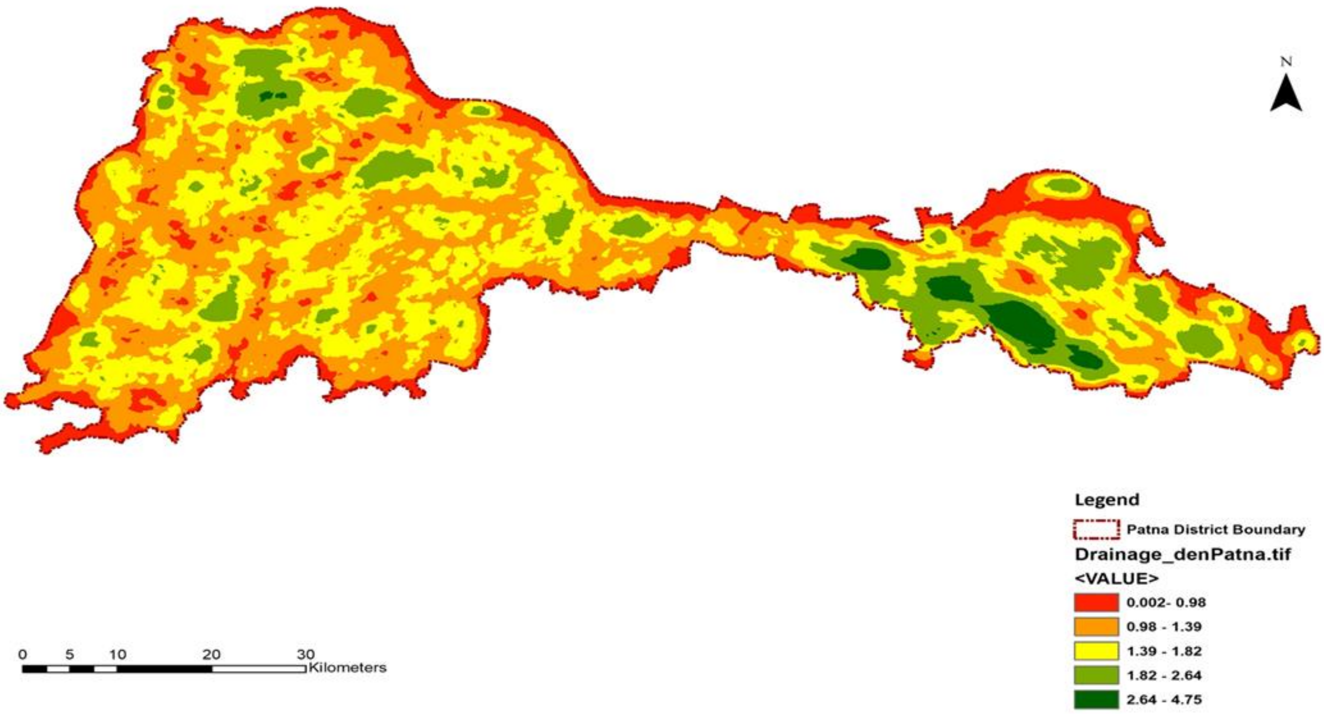


Figure 5 Drainage Density map of Patna District.

4.3 SLOPE

The slope of area defines the availability of water for replenishment and the roughness of the landscape of any region (Kundal P et al. 2004). On steeper slope groundwater may or may not be present but at lower slope water will certainly stay. Therefore there is not much variation in slope, so slope is less valuable for GWPZs and flood zones. Less slope results in more stability of water and will have higher value and higher slope will have less stability and results in low ranking values. So ranking was done based on this fact, and we don't consider slope map for drought potential zones delineation because slope will not affect much on drought zone because it can occur irrespective of slope at any place. The whole district is plain which constitute the loamy soil. The slope of the study area have been divided into five classes (0-0.82), (0.82-2.20), (2.20-4.05), (4.05-6.81), (6.81-23.47). Much of the field of research shows that 0 - 0.82% slope comprising area as 1475.48km^2 which indicates that the whole area of the district comes under the plain terrain. In figure- 6, the slope of the sample area is given.

4.4 RAINFALL

The precipitation serves as the key source of refuelling for groundwater supplies. The amount of precipitation significantly influences the amount of groundwater replenishment. Higher rainfall will result in higher infiltration resulting in easy groundwater recharge. Heavy and untimely rainfall will result in severe floods too, and also less and no rainfall will also result in severe drought too, so rainfall will have major influence on all three potential zones namely GWPZ, drought and flood zones. The study area's mean annual rainfall is about 1031 mm. The precipitation map for the research region was rated as 1022.89 and 1076.11 mm, in five categories with min and max precipitation, respectively. Higher ranks for GWPZs and flood zones are reserved for higher rainfall, but the inverse situation persists for drought regions. Figure-7 shows the study area's rainfall map.

4.5 SOIL

To demarcate the groundwater potential areas, soil is an essential factor. The soil map has been obtained from FAO for the study field. The soil type data shows that three distinct compositions of loamy soils primarily cover the study region. All three types with their composition are shown in Figure. Soil in lower elevation will have higher rank and vice-versa, for GWPZ and flood zones and for drought zones soil will be less or not influential therefore in this study, I ignored this map in drought zone delineation. Figure-8 shows the study area's soil map. Table-2 demonstrates different composition of soil of Patna district.

Table 2 Composition of soil of Patna district

S No.	Clay%	Silt%	Sand%
3681	21	38	41
3743	18	44	38
3808	21	35	44

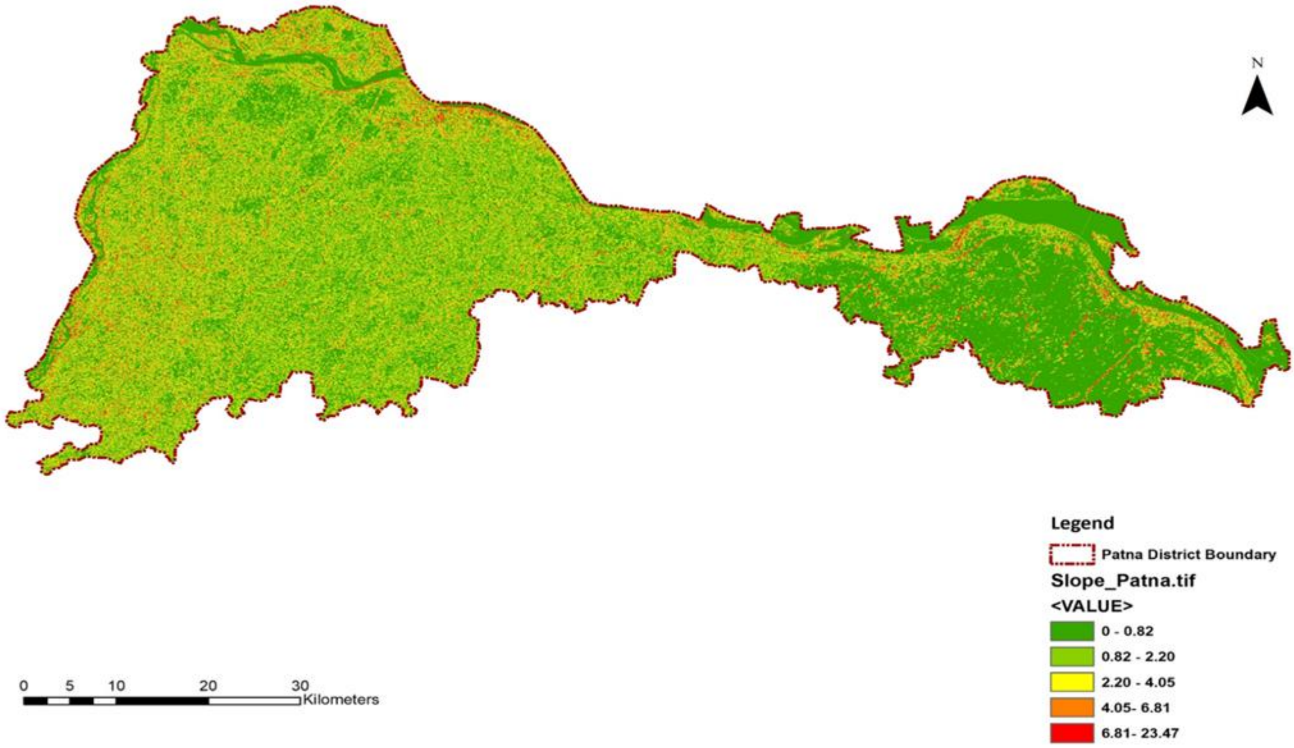


Figure 6 Slope map of Patna District.

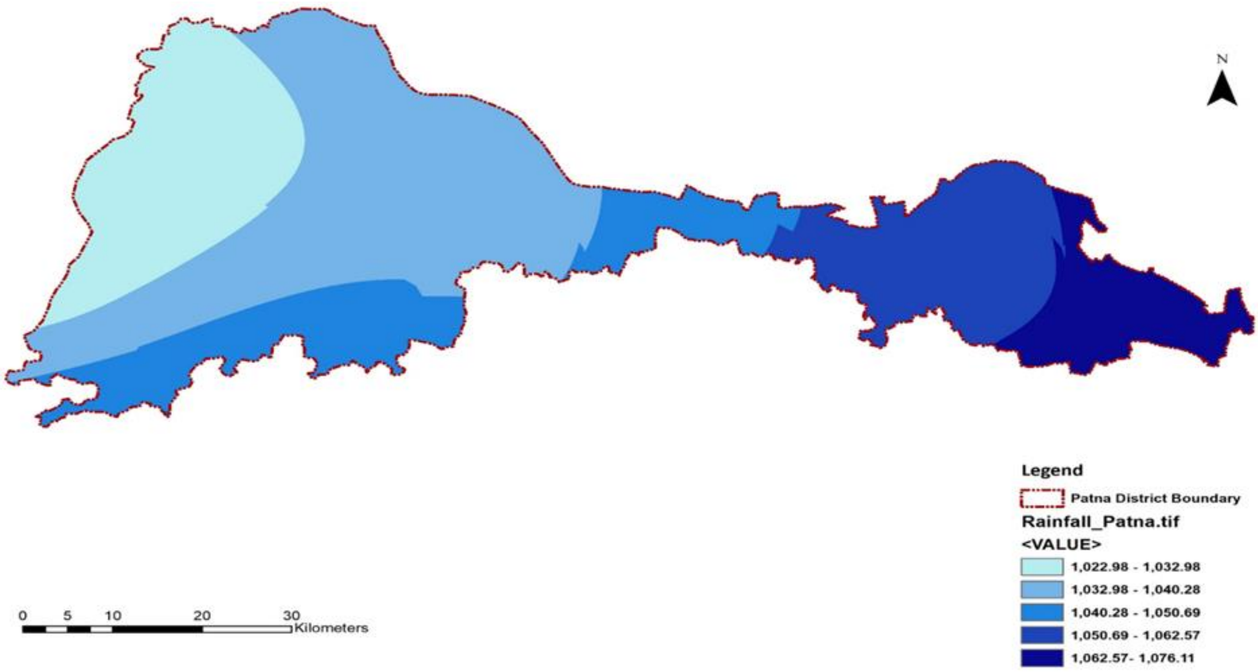


Figure 7 Rainfall map of Patna District.

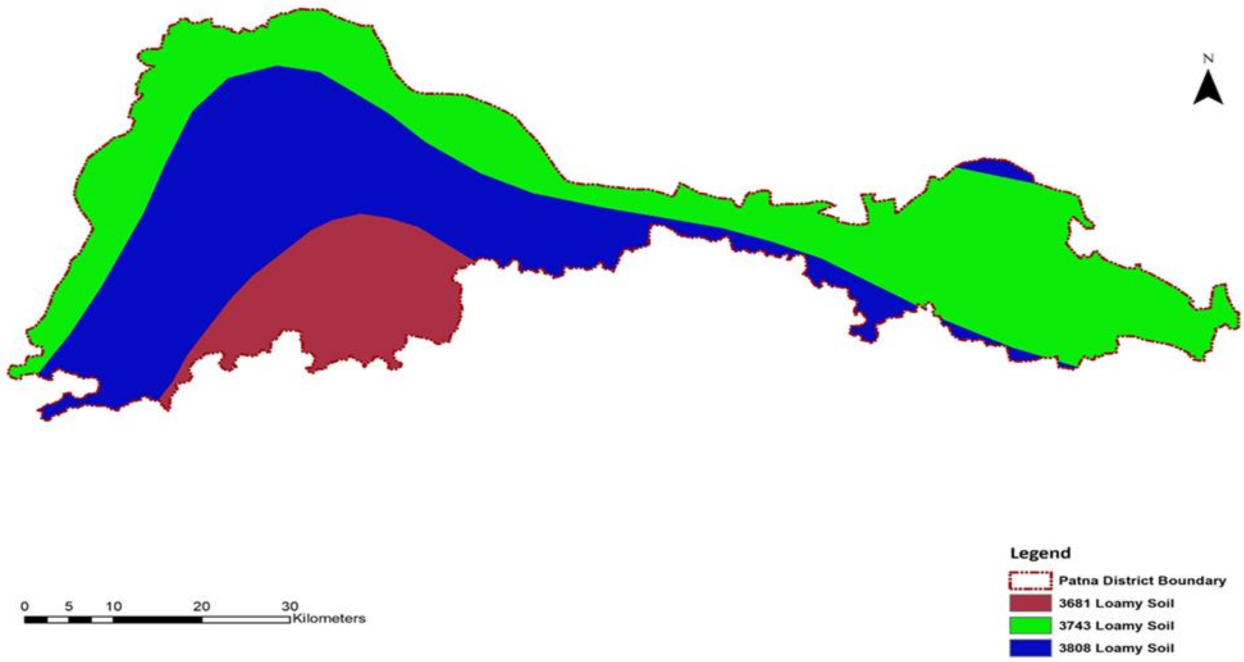


Figure 8 Soil map of Patna district.

4.6 LULC

Another significant parameter influencing the circulation and presence of groundwater in a region is LULC. The LU phenomenon has a stronger influence on the recovery of groundwater and also on the frequency of drought and floods. By looking at the LULC trend of the study region, the extent of land use, human habitation, and the length of uneven regions where groundwater can be recharged are determined. The LULC area map was graded into eight different classes namely Cropland, Built-up Land, Shrub land, Fallow Land, Water Bodies, Plantations, Grassland, and Permanent Wetlands. The cropland, waterbodies and plantations were deemed to be among the most appropriate replenish zone for GWPZs because they prefer the seepage of rainwater and irrigated water; hence, they were given higher ranking followed by built-up land because population tends to live near the place where groundwater is easily available and then permanent wetlands and then comes grassland, shrub land, fallow land in decreasing value of ranking respectively.

For drought zone delineation built-up and fallow land were given higher ranking followed by crop and shrub land and then plantation, grassland, waterbodies and permanent wetland were given value in decreasing order respectively.

For flood zone delineation cropland and built-up land were given higher ranks followed by shrub land and then waterbodies and grassland were given moderate rank and then plantation, permanent wetlands, and fallow land were assigned low ranks respectively.

The study region's land use and land cover are shown in figure-9.

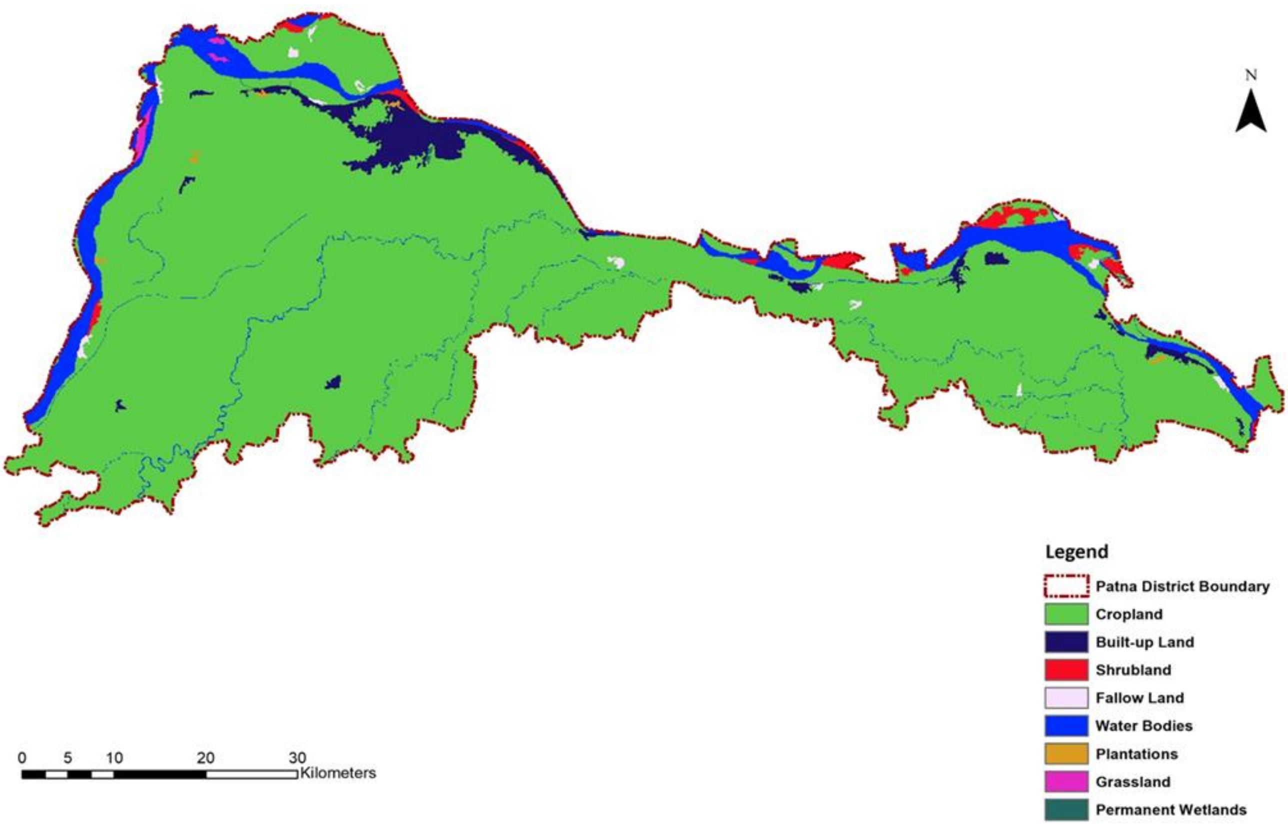


Figure 9 LULC map of Patna District.

4.7 DEM

Digital elevation models (DEMs) are collections of horizontally referencing spaced evenly elevation values either to a Universal Transverse Mercator (UTM) projection or to a spatial coordinate system with a significant effect on the demarcation of GWPZs, drought and flood regions. ASTER Global DEM Model Version3 with a resolution of 30 m were used for Patna district. DEM in study area is classified in five categories. For GWPZs lower elevation is more important and ranked with higher value and higher elevation with lower ranks and same follows for flood zone delineation because at lower elevation there will be more availability of ground water and also the possibility of rainwater staying at lower elevation so risk of occurrence of flood will be at higher side and for higher elevation there will be less ground water availability so rank will be less and in case of flood at higher elevation rainwater will not stay for long so less important and was given lower rank.

For drought zone delineation higher elevation will be of more importance so given high rank because of less rainwater staying at elevated area resulting in more prone to drought occurrence and lower elevation will have lower value because of more rainwater availability resulting in no or minimal risk of drought in particular area.

The study region's land use and land cover are shown in figure-10.

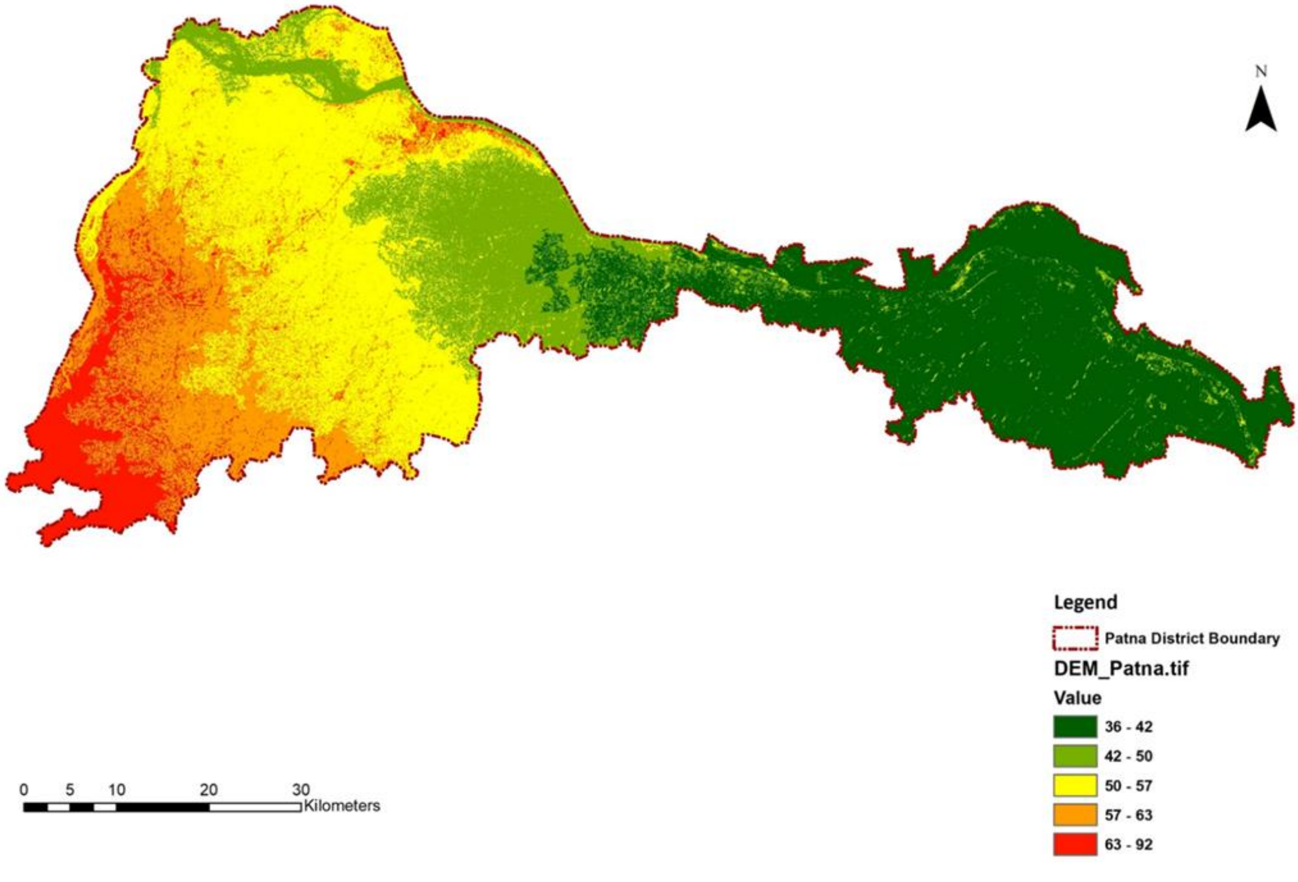


Figure 10 DEM map of Patna District.

4.8 GWPZs

The classification of various groundwater zones is focused on the overlay analysis method worked out by seven influencing factors in the ArcGIS for the Patna district in Bihar. In order to achieve a more objective outcome, the parameters and their sub-categories were evaluated in depth and relevant ranks and weights were allocated based on the expertise of professionals and references from different literature. The conceivable area thereby identified was divided into four sets like poor, moderate, good, and very good on the basis of the amount. As a result of better drainage density, plain field, greater rainfall intensity, and geomorphology, the eastern part indicating a very strong potential zone for groundwater has been seen. The western part of the district is more elevated than the eastern part with lesser drainage density, and less rainfall magnitude which leads to less availability of groundwater potential zones in this area. About 3.47% of the entire area was assigned to such a favourable region, 30.00% in good, 55.16% in moderate and 11.37% in poor for groundwater potential zones. Table-3 comprises of four GWPZ groups for the Patna district shows weights and ranks of different parameters, as well as Figure 11, it displays the spatial map.

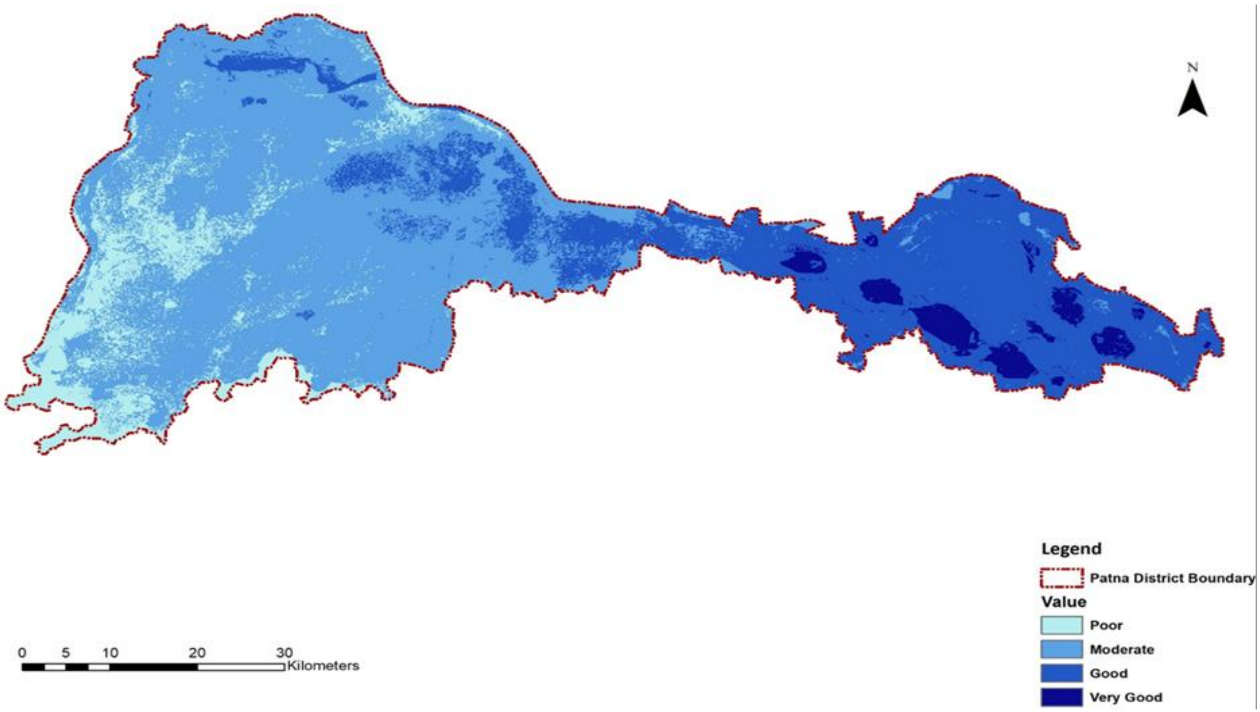


Figure 11 GWPZs map of Patna District.

Table 3 Allocated weight and rank to various thematic layers for GWPZ

Theme	Feature	Weight	Rank
Geomorphology	Younger alluvial plain	10	2
	Older flood plain		3
	Active flood plain		4
	River		5
	Pond		5
	Waterbodies		5
LULC	Crop land	10	5
	Built-up land		4
	Shrub land		2
	Fallow land		1
	Waterbodies		5
	Plantations		5
	Grass land		3
	Permanent wetlands		4
Soil	3681 Loamy Soil	5	3
	3743 Loamy Soil		5
	3808 Loamy Soil		4
Drainage density	0.002-0.98	25	1
	0.98-1.39		2
	1.39-1.82		3
	1.82-2.64		4
	2.64-4.75		5
Rainfall (mm)	1022.98-1032.98	15	1
	1032.98-1040.28		2
	1040.28-1050.69		3
	1050.69-1062.57		4
	1062.57-1076.11		5
DEM (m)	36-42	30	5
	42-50		4
	50-57		3
	57-63		2
	63-92		1
Slope	0-0.82	5	5
	0.82-2.20		4
	2.20-4.05		3
	4.05-6.81		2
	6.81-23.47		1

4.9 THE GROUNDWATER PROSPECTIVE ZONATION MAP VALIDATION

Utilizing well discharge data for 50 wells, ground water depth data gathered from CGWB, the groundwater potential zonation map was verified. For this, the pre-monsoon and post-monsoon groundwater deviation results were analysed for the year 2013. Patterns of water table rise and decline have been identified on these targeted wells, and it was categorised in five different ranges according to fluctuation in ground water level for pre and post monsoon data of year 2013. These ranges are -1.15 to 0.17 which indicates less fluctuation and results in continuous decrease of ground water in that zone because of located in mostly built up and agricultural area, where ground water is the major source of needing the demands of people and also for the crop growth. In this range total of 13 wells are found. Then ranges are 0.17 to 0.66(10 wells), 0.66 to 1.19(11 wells), 1.19 to 1.81(9 wells), all these regions are in the moderate fluctuation zones and the ranged value 1.81 to 4.06 indicates the more fluctuation and results in recharging of ground water easily because of located in near about waterbodies and in Ganga river vicinity and a total of 7 wells are found in this region. This statement therefore confronts the fact that the technique obtained for demarcating the possible groundwater region holds well and that adequate results have been obtained. Fig. 12, 13 &14 they display the spatial map.

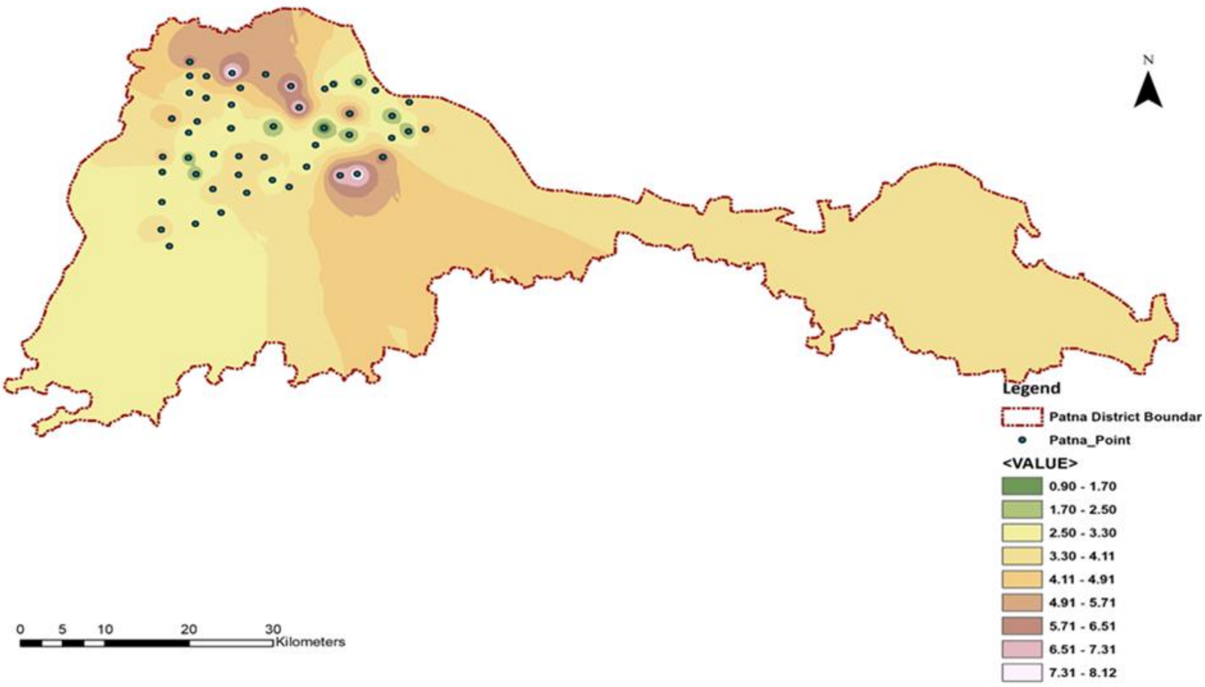


Figure 12 Pre-Monsoon water depth of Dug well of year 2013

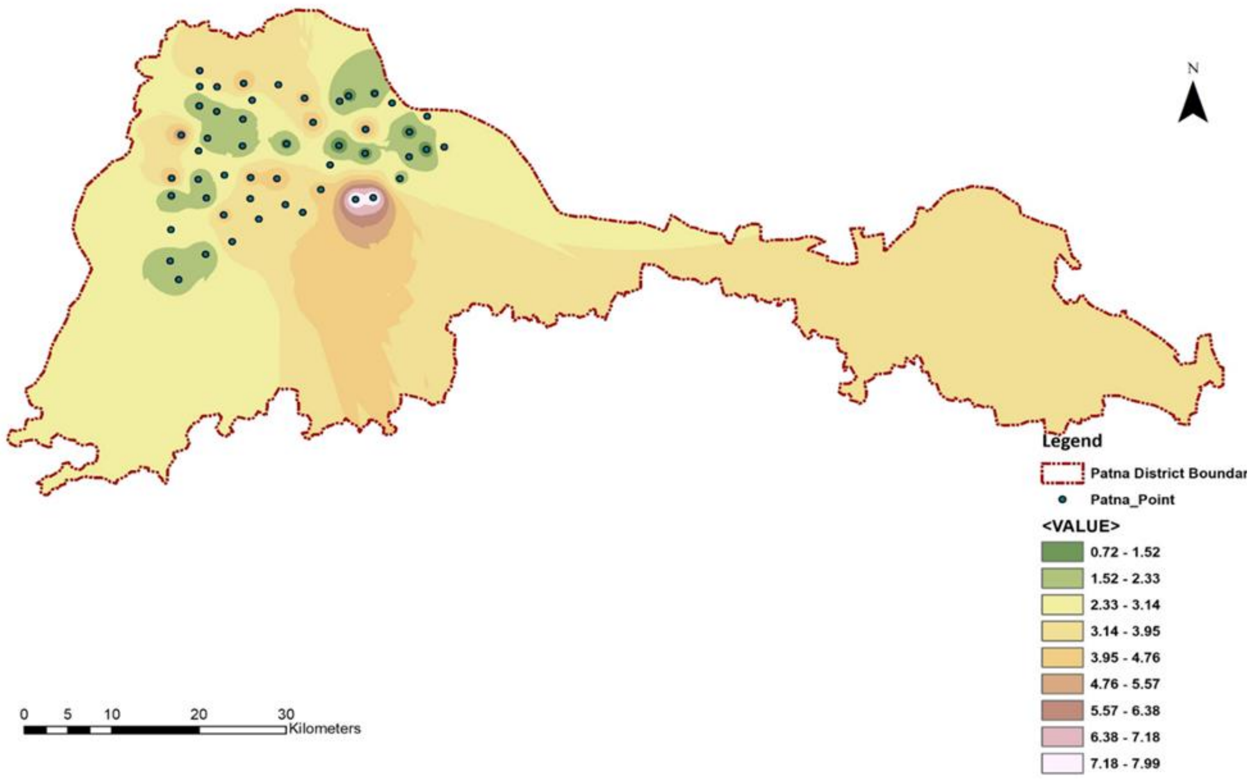


Figure 13 Post-Monsoon water depth of Dug well of year 2013.

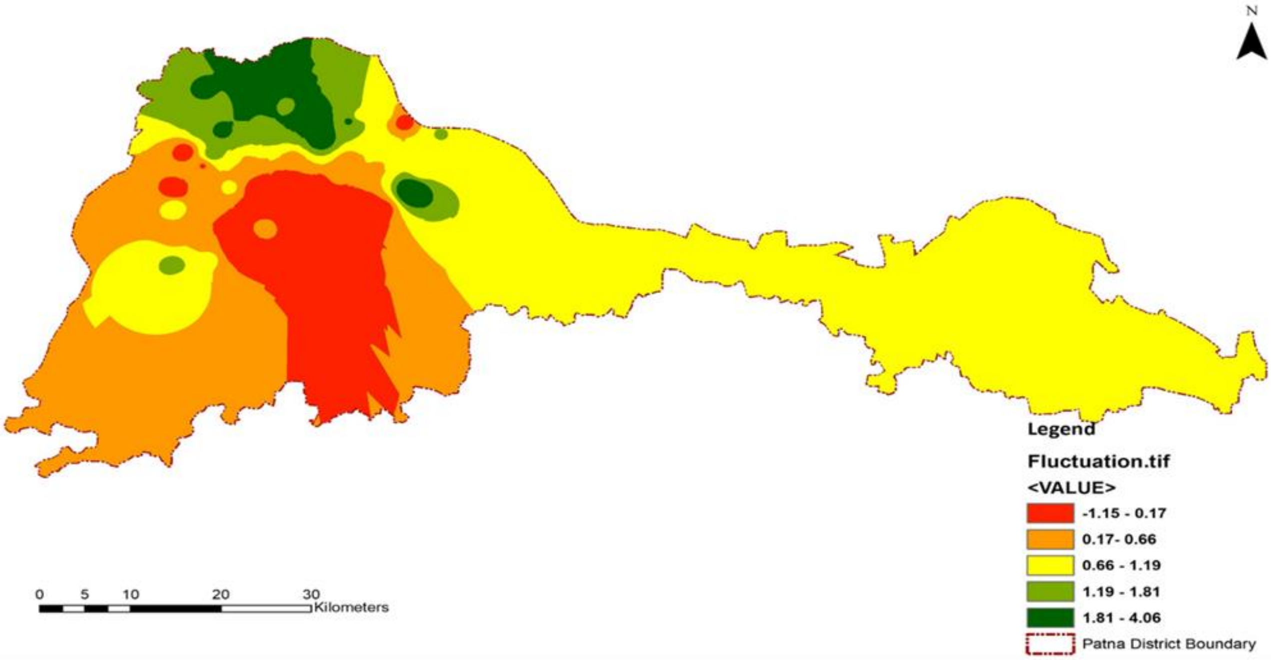


Figure 14 Fluctuation map of Patna district of year 2013.

4.10 DROUGHT POTENTIAL ZONES

The delineation of drought potential zones is centred on overlay analysis method performed out by five controlling parameters in the ArcGIS for the Patna district in Bihar. In order to achieve a more objective outcome, the parameters and their sub-categories were evaluated in depth and relevant ranks and weights were allocated based on the expertise of professionals and references from different literature. The conceivable area thereby identified was divided into four categories like no risk, low risk, moderate risk and high risk, based on the value. The eastern region after delineation shows that there are no or low risk zone because of located at lower elevation and higher rainfall occurrence and due to geomorphology too. But in western region most of the part is in moderate risk zone and very less part in high risk zones this is because district is more elevated at that region, plain terrain, lower rainfall extent, and due to geomorphology too. About 5.82%% of the overall area was divided into a no risk zone, 30.41% in low risk, 63.22% in moderate risk and 0.55% in high risk. So this data shows that there are less possibility of severe drought but there are possibility of drought occurrence in the district. Table-4 comprises four drought potential groups for the Patna district shows weights and ranks of different parameters, as well as Figure 15, it displays the spatial map.

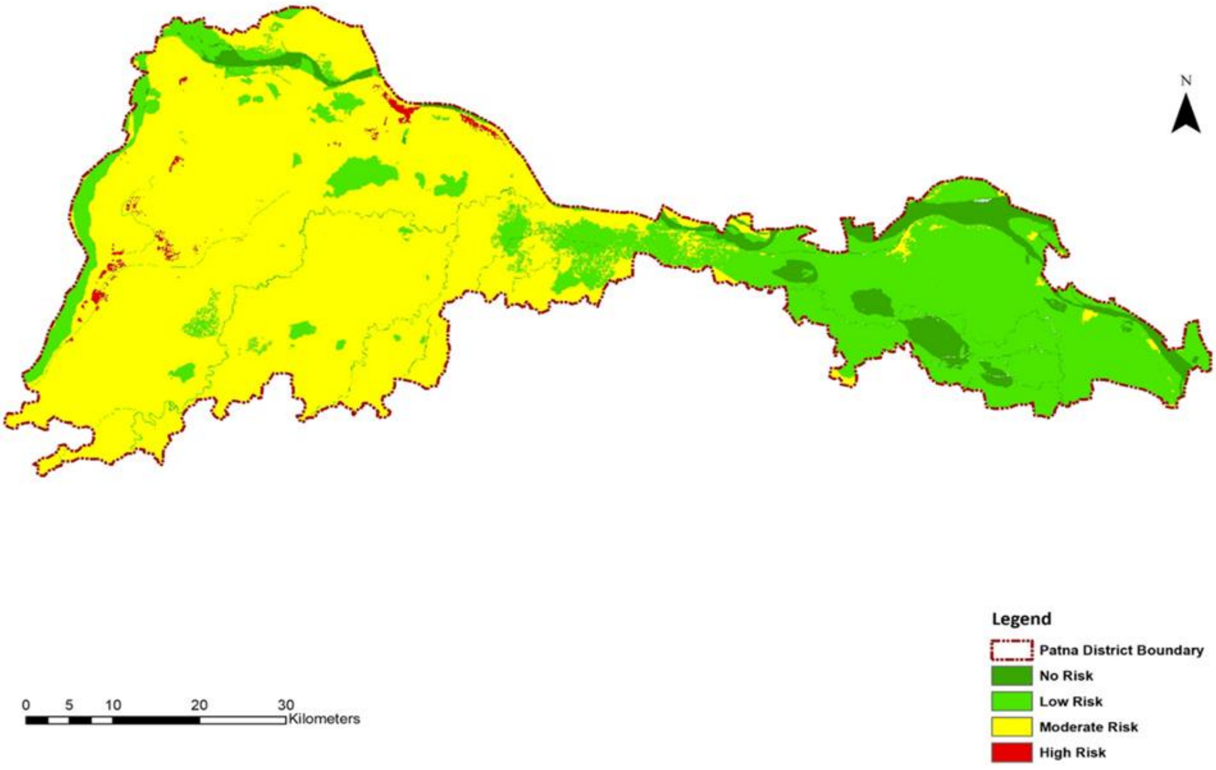


Figure 15 Drought potential zone map of Patna District.

Table 4 Allocated weight and rank to various thematic layers for Drought potential zones.

Theme	Feature	Weight	Rank
Geomorphology	Younger alluvial plain	8	5
	Older flood plain		4
	Active flood plain		3
	River		1
	Pond		2
	Waterbodies		1
LULC	Crop land	35	4
	Built-up land		5
	Shrub land		4
	Fallow land		5
	Waterbodies		1
	Plantations		3
	Grass land		2
	Permanent wetlands		1
Drainage density	0.002-0.98	25	5
	0.98-1.39		4
	1.39-1.82		3
	1.82-2.64		2
	2.64-4.75		1
Rainfall (mm)	1022.98-1032.98	20	5
	1032.98-1040.28		4
	1040.28-1050.69		3
	1050.69-1062.57		2
	1062.57-1076.11		1
DEM (m)	36-42	12	1
	42-50		2
	50-57		3
	57-63		4
	63-92		5

4.11 FLOOD POTENTIAL ZONES

The delineation of flood potential zones is centred on overlay analysis method performed out by seven controlling parameters in the ArcGIS for the Patna district in Bihar. In order to achieve a more objective outcome, the parameters and their sub-categories were evaluated in depth and relevant ranks and weights were allocated based on the expertise of professionals and references from different literature. The conceivable area thereby identified was divided into four categories like no risk, low risk, moderate risk and high risk, based on the value. Upon delineation, the eastern area suggests that there are high and moderate risk zone because of located at lower elevation and higher rainfall occurrence and due to geomorphology too, water will stay for long and will result in flood occurrence. But in western region most of the part is in low risk zone and very less part in no risk zones this is because district is more elevated at that region, lower rainfall magnitude, and due to geomorphology too, water will not stay for long in that region resulting in less flood risk. About 2.89% of the overall area was divided into a no risk zone, 62.35% in low risk, 31.16% in moderate risk and 3.60% in high risk. So this data shows that there are less possibility of occurrence of flood in western region of district but eastern region of district has chances of flood occurrence. Table-5 comprises four flood potential groups for the Patna district shows weights and ranks of different parameters, as well as Figure 16, it displays the spatial map.

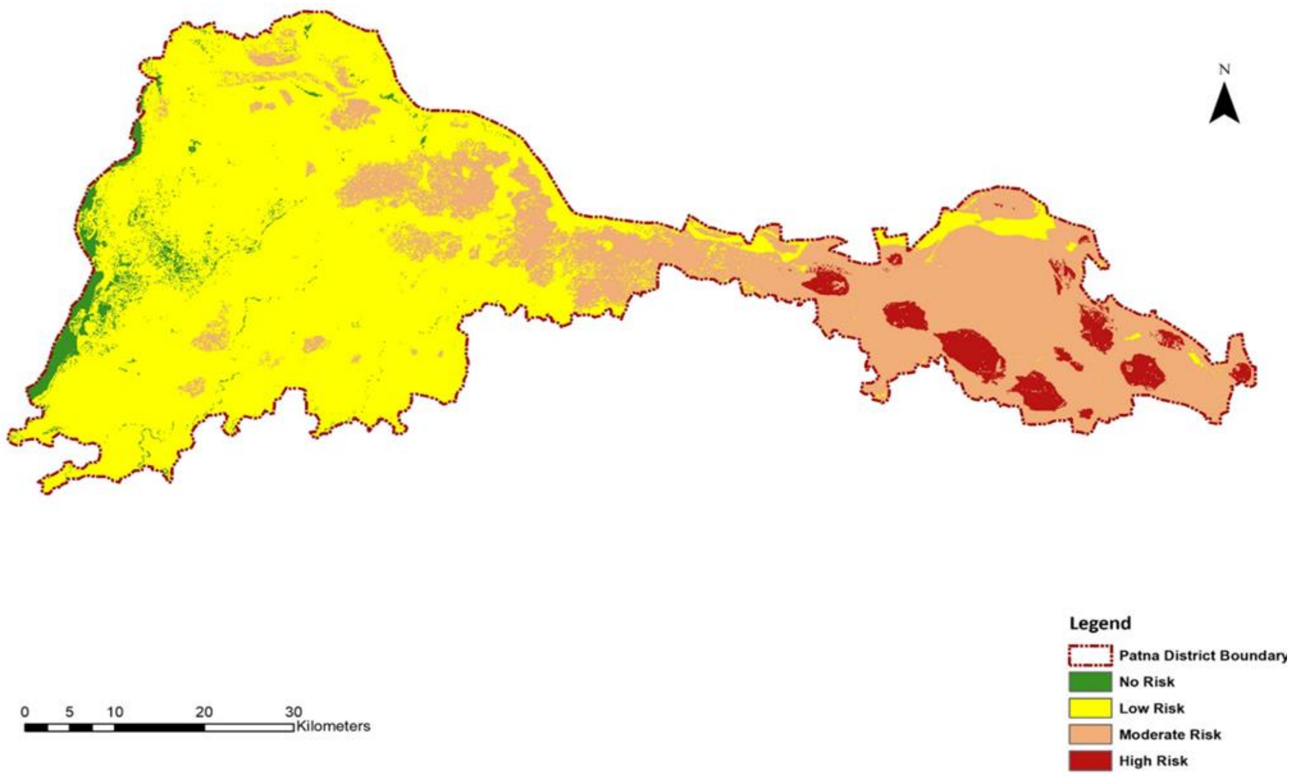


Figure 16 Flood potential zone map of Patna District.

Table 5 Allocated weight and rank to various thematic layers for Flood potential zones.

Theme	Feature	Weight	Rank
Geomorphology	Younger alluvial plain	8	2
	Older flood plain		4
	Active flood plain		5
	River		3
	Pond		3
	Waterbodies		3
LULC	Crop land	22	5
	Built-up land		5
	Shrub land		4
	Fallow land		1
	Waterbodies		3
	Plantations		2
	Grass land		3
	Permanent wetlands		2
Soil	3681 Loamy Soil	5	1
	3743 Loamy Soil		3
	3808 Loamy Soil		2
Drainage density	0.002-0.98	20	1
	0.98-1.39		2
	1.39-1.82		3
	1.82-2.64		4
	2.64-4.75		5
Rainfall (mm)	1022.98-1032.98	20	1
	1032.98-1040.28		2
	1040.28-1050.69		3
	1050.69-1062.57		4
	1062.57-1076.11		5
DEM (m)	36-42	20	5
	42-50		4
	50-57		3
	57-63		2
	63-92		1
Slope	0-0.82	5	5
	0.82-2.20		4
	2.20-4.05		3
	4.05-6.81		2
	6.81-23.47		1

CHAPTER 5
CONCLUSION

The study showed that the methods and strategies used were extremely efficient as they enabled the analyst to make a decision based upon its impact of the aspects considered and also supported by ArcGIS to better visualize the result's geographical extent. The conceivable area identified was divided into four categories like poor, moderate, good, and very good extending about 11.37%, 55.16%, 30.00%, and 3.47%, of area respectively. The result was highly influenced by factors such as drainage density, DEM and rainfall, while components such as soil, LULC, slope and geomorphology had relatively less impact. Using the groundwater fluctuation data, the methodology applied was also verified and was discovered to have a strong agreement. These findings can be used to take up the further investigation and introduce water management initiatives in the appropriate zone by government authorities and concerned consultants. For legislators, engineers, experts, scientists and the regional water regulatory body (CGWB), the GWPZ map created in this thesis can be very helpful in finding the potential sites for groundwater reconnaissance. In order to ensure the long-term viability of this precious commodity, it could also be useful in formulating successful groundwater extraction strategies. For drought potential locations, the simulation results are grouped into four classes 1-no risk, 2-low risk, 3-moderate risk and 4-high risk extending about 5.82%, 30.41%, 63.22% and 0.55% of area respectively. The result was strongly influenced by components such as LULC, drainage density, and rainfall, while factors such as DEM and geomorphology had significantly less significance.

For flood potential locations, the simulation results are grouped into four classes 1-no risk, 2-low risk, 3-moderate risk and 4-high risk extending about 2.89%, 62.35%, 31.16% and 3.60% of area respectively. The result was strongly influenced by components such as DEM, LULC, drainage density, and rainfall, while factors such as soil, slope and geomorphology had significantly less significance. Valid and credible findings are therefore given by this approach adopted in this study, which was an unmapped and rarely acknowledged subject in past studies for the research area.

These results for drought and flood potential zones can be utilized by government authorities to carry out further exploration and implement drought and flood management strategies in the affected zone. It will also help government to be prepared for worst scenario in more risky zones of drought and flood and also to place NDRF teams near about the higher or moderate risk zones to start relief process as fast as possible in the affected region in the Patna district.

CHAPTER 6

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